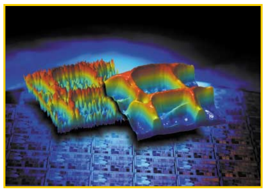
Research Focus

Development of computer vision techniques for high-precision quantitative analysis of features in nano-scale images and image sequences.

Research at Intel
Computational Nanovision



Noisy image from a direct-write nano-machining tool showing sub-micrometer silicon structures.

Recent developments in nanotechnology and life sciences are creating structures measured in nanometers. Simultaneously, silicon manufacturing technology is shrinking critical dimensions of structures to scales well below 100 nanometers. Successful applications in these nanotechnologies require extremely high-precision analysis tools for measurement and visual feedback.

There are a number of significant challenges associated with quantitative measurements of nano-scale features. Noise and insufficient spatial sampling by imaging tools, as well as artifacts caused by the imaging mechanisms themselves, are the main sources of errors and can render visual analysis by human observers impossible. In addition, the structures and dynamics of nano-scale objects exhibit a high degree of variation imposed by the natural variability of atomic surfaces and by stochastic behavior.

Despite this randomness, the nano-scale world is dominated by elementary physical processes and phenomena that constrain possible shapes and dynamics of structures. To solve computer vision problems in nano-scale dimensions, we must exploit physical models of stochastic systems and blend them with state-of-the-art computer vision and image processing techniques. The Computational Nanovision project, launched in March 2002, is exploring this challenge. Our focus is well balanced between basic research and work that can be transferred to Intel's world-class manufacturing technology. This combination provides a unique environment for researchers.

Besides silicon manufacturing, our research is directly applicable in the growing field of Biotechnology. We are actively engaging with researchers in this field to develop new measurement tools and techniques for analyzing nano-scale particles.

In carrying out our research, we are collaborating with a number of university researchers at MIT, UCLA, and Brown University. As the project progresses, we will share our knowledge and exchange ideas through presentations, publications, and participation in key conferences.

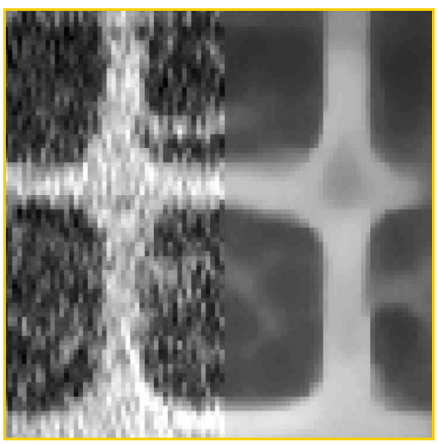
Research Agenda

Our research agenda is constantly evolving. The following is a sample of research activities in progress.

We are taking a model-based approach to our research in Computational Nanovision. Because of Intel's deep experience in semiconductor manufacturing processes, we have detailed models of the nanostructures of microprocessors. We know where features should appear, even if they are not visible to the eye. We are using these detailed blueprints, along with our familiarity with existing imaging tools and our knowledge of the physics underlying image formation, to develop new techniques for analyzing nanostructures within images. Initially, our research team is exploring two model-based image sequence analysis techniques: image reconstruction and feature detection and classification.

Image Reconstruction

The smaller the structure, the noisier the image. As nanostructures continue to shrink in size, we are reaching a point where it will be virtually impossible to see particular features within the image, such as parts of transistors in a micro-processor. We are exploring quantitative methods of reconstructing nanostructure images so the user can see features that are not visible in the noise. We are investigating model-based, nonlinear techniques, such as anisotropic diffusion, to detect features within noisy images.

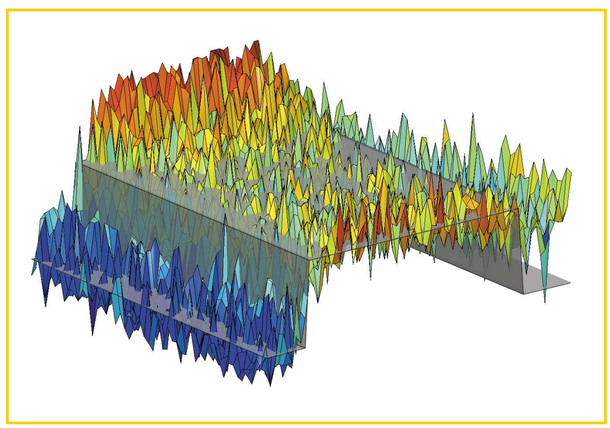


Left: Noisy image from a direct-write nano-maching tool showing sub-micrometer silicon structures.

Right: De-noised real-time reconstruction of the image by nonlinear spatio-temporal filtering techniques.

Nanofeature Detection and Classification

Some of our applications require real-time capability to allow for fast visual feedback from manufacturing tools. Even if a nanostructure image can be reconstructed, currently the tool operator must make a decision — such as determining when a certain structure of interest is visible in the noisy image. Automated visual feedback requires quantitative data analysis supported by model knowledge of the observed structures. We are exploring probabilistic techniques for automatically detecting and classifying nanofeatures, to assist users and to reduce the risk of human error. By rigorously exploiting domain knowledge we are able to extract information from degraded images beyond the limits of human perception.



Detection of a wire in noisy data. Color: Noisy image of wire. Grey: Estimated position based upon statistical model

People

Principal Investigator: Horst Haussecker, Ph.D.

Horst Haussecker is a member of the Senior Research Staff at Intel's Microprocessor Research Lab and leader of the Computational Nanovision research project. His general research interests include physics-based computer vision, image sequence analysis, infrared thermography, and application of digital image processing as a quantitative instrument in science and technology. He is co-editor and main contributing author of two books and has authored or co-authored more than 50 peer-reviewed technical articles.

Dr. Haussecker received his M.S. and Ph.D. in physics from Heidelberg University. Prior to joining Intel in 2001, he was a member of the Research Staff at the Xerox Palo Alto Research Center (PARC), where he was involved in image sequence analysis and collaborative information processing in sensor networks. From 1996 to 1999, Dr. Haussecker was a researcher at the Interdisciplinary Center for Scientific Computing, Heidelberg University, where he worked on image sequence analysis for analyzing complex dynamic processes with varying brightness patterns. During research visits at the Scripps Institution of Oceanography, UC San Diego between 1994 and 1997, he developed image sequence processing techniques for quantitative analysis of microscopic transport processes across the air-sea interface.

Research Team

The Computational Nanovision Project involves collaboration among researchers at Intel and several universities. The core team members include Senior Researcher, Yoram Gat; Researcher, Scott Ettinger; and Visiting Scientist, Hanno Scharr. This core team works closely with other Intel researchers as well as with application groups within Intel's corporate technology and manufacturing organizations.

Left to right: Yoram Gat, Scott Ettinger, Horst Haussecker, and Hanno Scharr.

For more information on Computational Nanovision, please visit:
http://www.intel.com/research/nanovision

About Intel Research

In a future world of proactive computing, billions of tiny, powerful, connected devices throughout the environment will anticipate our needs and take appropriate action on our behalf. With the formation of Intel Research in 1999, Intel began funding research into the emerging and disruptive technologies required to translate this vision into reality.

Intel has initiated several projects in support of proactive computing. A number of strategic research projects are being carried out internally, within Intel's research and development labs. These projects cover a broad range of disciplines, including MEMS, precision biology, ad hoc networks, extreme networked systems, ubiquitous computing, novel storage, live databases, statistical models, computational nanovision, robotics, machine learning, supply chain visualization, distraction-free systems, proactive healthcare, and ethnography.

Complementary research into proactive computing is being conducted externally through the Intel Research Network of labs, an innovative partnering between industry and academia. The labs, located near major universities, are wholly owned and funded by Intel but operate using a uniquely open and collaborative model. Much of the research they generate will be published and shared widely. Currently there are four labs in the network, in Berkeley, Pittsburgh, Seattle and Cambridge, England

The Intel Research Network of labs builds upon Intel's strong history of research and development, both within the company and through more than 250 funded university projects throughout the world. Intel also supports research institutions through a variety of programs, including Intel forums, visiting faculty collaboration, and joint Intel-university research projects. Intel is an active participant in Sematech, the Semiconductor Research Corporation, and other industry consortia.

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